

Claims

What is claimed is:

1. A video camera with enhanced image clarification comprising:

~~means for producing a sequence of digital images of an object, which object is an optical system consisting of a lens and an adaptive optical device which produces an optical image of an object which is being continuously distorted by time-varying aberrations of an optical medium;~~

~~an adaptive optic device in said optical system arranged for receiving said sequence of digital images and canceling said aberrations; to cancel said aberrations and to produce clarified, in-focus, optical images of said object in the lens' focal plane;~~

~~a detector array arranged to receive said in-focus optical images and to produce a sequence of digital in-focus images, namely, $I(k), I(k-1), \dots$, where k is a time index; and~~

~~a digital processor connecting with said adaptive optic device for performing real-time control of said adaptive optic device; and~~

~~a digital sequential diversity processor connecting with said digital processor for providing which uses the said sequence of digital in-focus images to provide real-time control signals to $T(k), T(k-1), \dots$, for said adaptive optic device to thereby cancel said aberrations.~~

2. The camera of claim 1 wherein said sequential diversity processor utilizes diversity $D(k-1)$, along with current and previous data images, $I(k)$ and $I(k-1)$, as diverse images to estimate $Q(k-1)$ a residual phase aberration in said optical system, whereby $D(k+1) = -Q(k-1)$.

3. The camera of claim 1-2 wherein said sequential diversity processor adds $T(k-1)$ to $D(k)$ to get the control signal for said adaptive optic device at time k , that is, $T(k) = T(k-1) + D(k)$.

$T(k)$ is added to $D(k+1)$ whereby $T(k+1) = T(k) + D(k+1)$.

4. The camera of Claim 1 whereby the ~~S~~sequential diversity processor imaging apparatus comprising:

~~means for receiving a sequence of images of an object, said object being continuously distorted by a changing optical medium;~~
~~an AO device in optical proximity with said receiving means for canceling aberrations introduced by said medium to thereby provide~~
~~estimates the aberrations distorting the object and calculates control signals for~~
~~said adaptive optic device to cancel said aberrations; and whereby the imaging~~
~~system produces solely adapted in-focus images of said object. No other~~
~~auxiliary equipment or signal, like an intentionally defocused image, is needed to~~
~~control the adaptive optic device.~~

~~a detector array arranged for receiving said solely adapted in-focus images and producing digital image representations thereof; and~~
~~a sequential diversity processor connecting with said detector array and said AO device, said sequential diversity processor receiving said digital image representations from said detector array and providing sequential control signals to said AO device to enable said AO device to cancel said aberrations.~~

5. The sequential diversity imaging apparatus of Claim 4 wherein said sequential diversity processor calculates a sequence of diversities corresponding to said aberrations according to a predetermined diversities equation whereby

$W(k) = \text{unknown distorting wavefront at time } k$

$T(k) = \text{phase put on the AO at time } k$

$G(k)$ = compensated phase to be estimated by a diversity algorithm =
 $W(k) + T(k)$ (1)

$I(k)$ = Measured image at time k .

$D(k)$ = Diversity phase.

$I(k-1)$ is the first image and $I(k)$ is the diversity image and the diversity phase is the change in the AO phase from time $k-1$ to time k . Thus,

$D(k) = T(k) - T(k-1)$ (2)

The phase diversity algorithm is set up to estimate $G(k)$, the compensated phase at time k .

$Q(k) = W_1(k) + T(k)$, (3)

set $T(k+1) = W_1(k)$, (4)

Solving (3) for $W_1(k)$ and substituting it into (4),

$T(k+1) = Q(k) + T(k)$,

$T(k) = Q(k-1) + T(k-1)$.

Insert equation (5) into (2) as follows, $D(k) = (Q(k-1) + T(k-1)) - T(k-1) = Q(k-1)$ (6) to provide the specification for the diversity phase at time k .

6. The sequential diversity imaging apparatus of Claim 4 wherein said control signals for said AO device are determined according to the following control equation:

$T(k) = T(k-1) + D(k)$ (7).}

7. A method for determining aberrations caused by an atmosphere and controlling an AO device in an optical system to eliminate said aberrations comprising the steps of:

providing a plurality of solely in-focus images, each of said solely in-focus images having a known diversity selected from the group consisting of phase, wavelength, or spatial shift;

determining an unknown object and parameters of said atmosphere causing said aberrations;

generating a plurality of sequential frames of a video recording of said object to provide diversity images; and
inputting said diversity images to a sequential processor connected with said AO to thereby control said AO and eliminate said aberrations.

8. The method of Claim 7 wherein said sequential diversity processor calculates a sequence of diversities corresponding to said aberrations according to a predetermined diversities equation wherein:

$W(k)$ = unknown distorting wavefront at time k .

$T(k)$ = Phase put on the AO at time k .

$G(k)$ = Compensated phase to be estimated by a diversity algorithm = $W(k) + T(k)$ (1)

$I(k)$ = Measured image at time k .

$D(k)$ = Diversity phase.

Said diversity phase defining a change in the AO phase from time $k-1$ to time k .
Thus,

$D(k) = T(k) - T(k-1)$ (2)

The phase diversity algorithm is set up to estimate $G(k)$, the compensated phase at time k . Set the estimate $Q(k)$ from equation (1),

$Q(k) = W_1(k) + T(k)$ (3)

$W_1(k)$ is an estimate of $W(k)$, the unknown phase at time k . At time $k+1$ the AO phase is set to the negative of the unknown wavefront at time $k+1$.

Set $T(k+1) = -W_1(k)$, where w_1 is the wavefront at time k (4)

Solving (3) for $W_1(k)$ and substituting it into (4),

$T(k+1) = Q(k) + T(k)$,

set $T(k) = Q(k-1) + T(k-1)$.

Insert equation (5) into (2) to get

$D(k) = (-Q(k-1) + T(k-1)) - T(k-1) = -Q(k-1)$ (6)

to provide the specification for the diversity phase at time k .

9. The method of Claim 7 wherein said control signals for said AO device are determined according to a predetermined control equation.